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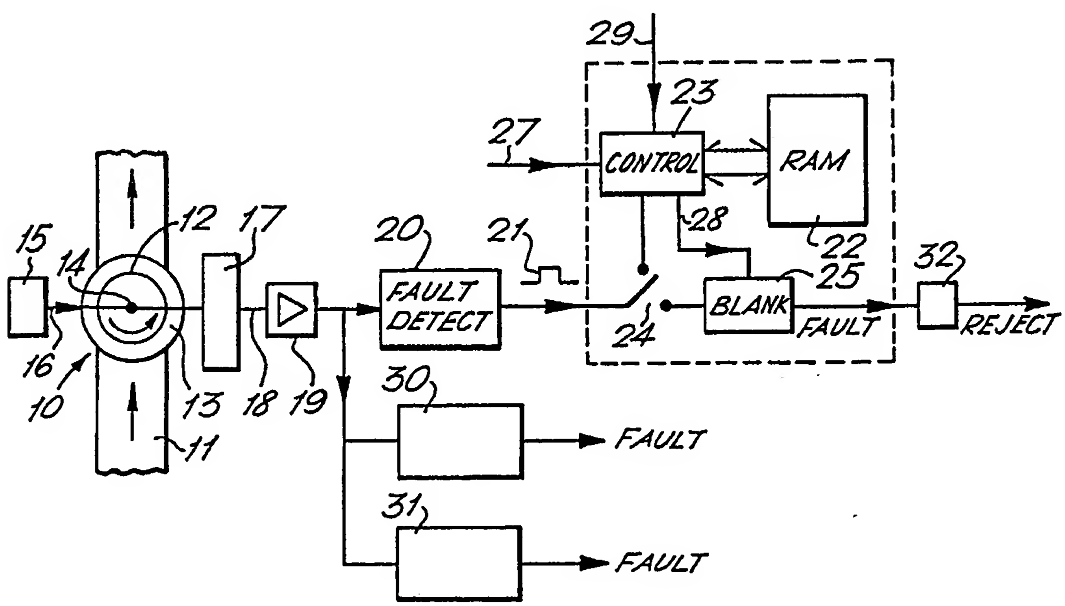
G1A

(54) Apparatus for the inspection of translucent containers

(57) The apparatus comprises means (13) for rotating a container (12) within a scanning zone (10), wherein a spot beam of light (16) repeatedly scans the container in a direction substantially parallel to its axis of rotation. A sensor (17) provides a signal representing the amount of transmitted light falling thereon to a fault detection circuit (20) adapted to examine the signal and to generate a fault-indicating signal (21) when a predetermined criterion is fulfilled. A digital storage means (22) has stored therein binary information identifying those scan positions of the beam (referred to herein as fault-invalid positions) in respect of which fault-indicating signals may be generated from an acceptable container. Suppression means (23, 25) responsive to the stored binary information suppresses any fault-indicating signal generated in respect of a fault-invalid position of the beam. Binary information is stored by previously scanning many containers known to be acceptable, and storing a digital indication of each fault-indicating signal generated during each individual scan of the container at an address in the storage means (22) corresponding to the current scan position of the beam.



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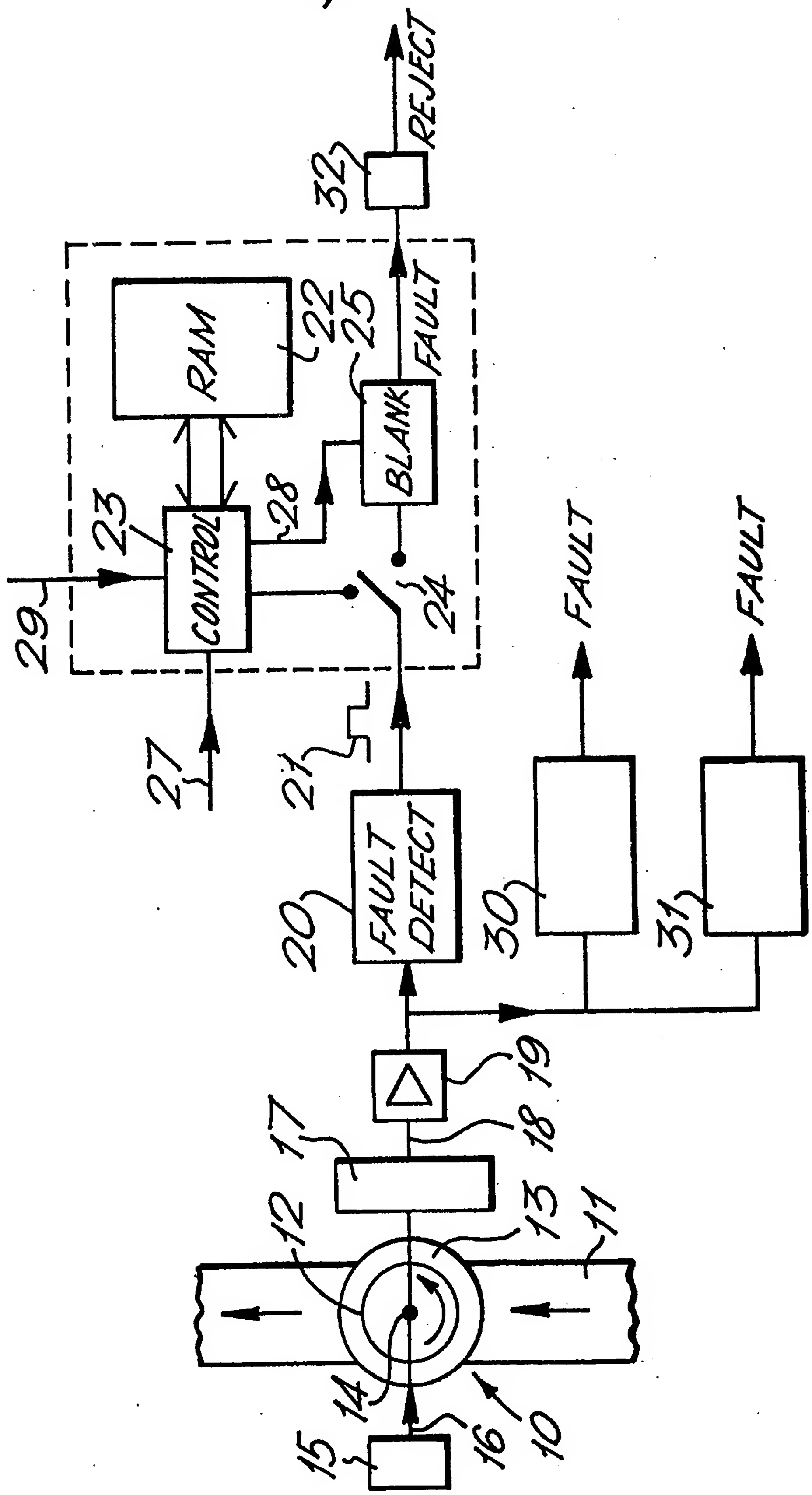
REJECT
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SPECIFICATION

Apparatus for the inspection of translucent containers

This invention relates to an apparatus for the inspection of translucent containers, such as glass bottles, for faults.

Bottle inspection systems are known wherein a rotating bottle is scanned by a single vertically scanning spot beam of light passing completely through the bottle from one side to the other and intersecting the vertical axis of the bottle; see U.K. Patent Specifications 1 206 136 and 1 430 547.

In the systems disclosed in these prior Specifications a light collector is arranged to provide an electrical signal representing the amount of light falling thereon from the beam after transmission through the bottle, such signal thereafter being compared with a reference threshold level to generate a fault-indicating signal when the light collector signal falls below the threshold level.

In order to allow for the fact that in general the quantity of light transmitted through an acceptable bottle will vary according to the vertical position of the beam due, for example, to neck rings, regions of embossing and lettering on the main body of the bottle, and the push-up at the base of the bottle, the second of the above mentioned U.K. Patent Specifications discloses the use of a variable threshold level which is a function of the vertical position of the beam relative to the container.

However, such an arrangement requires a laborious manual setting-up procedure for each different bottle type, involving the fine adjustment of potentiometers which determine the threshold level at each vertical position of the beam. Futhermore, such settings are liable to drift over a period of time, or change with temperature, so that eventually an unacceptable proportion of good bottles are rejected, and the apparatus has to be re-callibrated at regular intervals.

It is therefore, an object of the present invention to provide an improvement in the known systems referred to above which avoids this time-consuming manual setting-up procedure.

Accordingly, the present invention provides an apparatus for the inspection of translucent containers, the apparatus comprising a scanning zone, means for rotating a container within the scanning zone, means for generating a spot beam of light and causing it to repeatedly scan the container in a direction substantially parallel to the axis of rotation of the container, an opto-electronic light collector for providing a signal representing the amount of light falling thereon from the beam after transmission through the container, a fault detection circuit adapted to examine the signal from the light collector according to a predetermined criterion to generate a fault-indicating signal when such criterion is fulfilled, a digital storage means having stored therein binary information identifying those scan positions of the beam (referred to herein as fault-invalid positions) in respect of which fault-indicating signals may be generated according to the said criterion from an acceptable container, and suppression means responsive to the stored binary information for suppressing any fault-indicating signal generated in respect of a fault-invalid position of the beam, wherein the contents of the storage means are the cumulative result of previously scanning a large number of containers which have been determined to be acceptable, and storing a digital indication of each fault-indicating signal generated during each individual scan of the container at an address in the storage means corresponding to the current scan position of the beam.

The contents of the storage means, which is preferably a random access memory (RAM), are preferably the cumulative results of previously scanning a large number of containers (for example 50) which have been determined to be acceptable by other means (for example by manual inspection and measurement), and storing a predetermined binary digit in the RAM in respect of each fault-indicating signal so generated, the bit cells of the RAM being addressed for each individual scan of the container in the same predetermined sequence so that each fault-indicating signal is stored at a bit cell location corresponding to the current scan position of the beam. The number of containers previously scanned in this way and contributing to the cumulative result in the RAM sets the degree of tolerance afforded by the system.

The suppression of the fault-indicating signals may take various forms. In the preferred embodiment, however, this is achieved by reading out the contents of the RAM in the said predetermined sequence in synchronism with each individual scan of the container, and blanking any fault-indicating signal which occurs simultaneously with an output of the RAM which identifies the current scan position of the beam as being a fault-invalid position. The read-out of the RAM should, of course, be non-destructive.

In order to mitigate the effects of a faulty (stuck) bit cell of the RAM not being set by a fault-indicating signal, or the possible loss of individual bits of stored information by, for example, the incidence of cosmic rays or other ambient radiation, it is desirable to enter the information accumulated in the RAM in duplicate, for example, by writing such information in identical sequence in two or three columns of the memory. In such case the above-mentioned suppression takes place if a significant bit appears in any one or more of the two or three columns of the memory in the bit cell corresponding to the current scan position of the beam, each of such columns being read out in synchronism with the beam while inspecting a container.

The criterion used in the invention by the fault detection circuit for detecting faults may be of any desired kind. Thus the fault detection circuit may operate by comparing the signal from the light collector with a threshold level in an automatic threshold tracking circuit (ATTC) as in the case of

the arrangement disclosed in our European Patent Specification No. 0016551. An ATTC circuit is a comparison circuit wherein the threshold level against which the sum signal is compared is derived from the sum signal itself so as to accommodate containers whose wall thickness and/or colour density may vary significantly. The threshold signal is effectively a smoothed version of the sum signal which lags the latter and is offset from it by a predetermined amount.

In the preferred embodiment, however, the fault detection circuit associated with the light collector is adapted to differentiate the signal therefrom so as to provide a further signal representing the rate of change of amplitude of the light collector signal, and to compare the further signal with a reference threshold level so as to generate a fault-indicating signal when the rate of change of amplitude exceeds the threshold level.

In this case it is advantageous, for reasons which will be explained later, to direct the further (differentiated) signal into a plurality of independently operating channels in each of which the signal is compared with a different reference threshold level, each such channel having its own digital storage means. The suppression means in such an arrangement may either be common to all channels, or a respective suppression means may be provided for each channel.

Whatever criterion is chosen for fault-detection, it is generally necessary for the same criterion to be used both in generating the initial accumulated information in the (or each) RAM and for the subsequent testing of containers. An exception to this, however, is where the criterion used for testing is less sensitive than the criterion used for the initial accumulation of information, i.e. it cannot generate a fault-indicating signal from an acceptable container outside the fault-invalid regions defined by the RAM. A particularly advantageous arrangement, when the same differentiating and threshold comparison circuit is used both to generate the contents of the RAM and to subsequently inspect the containers, is to set the reference threshold for the first operation (accumulation of RAM contents) at a lower level than that used in the subsequent inspection. This enables one to accommodate acceptable undulations in the internal surface of the container which in conventional bottle manufacture tend to be greater than those in the external surface and thus may fall outside the tolerance extablished by the RAM despite passing a large number of acceptable containers through the system. Furthermore, a fault-detecting circuit set to detect occulsive faults by a comparison with a fixed threshold can be used in conjunction with a RAM whose contents were accumulated by an ATTC circuit or differentiation, provided that the fixed threshold level is chosen to represent a level of opaqueness greater than that occuring anywhere outside the fault-invalid regions defined by the RAM. Indeed, a fixed threshold is most efficient in detecting regions of "smoke" in the glass, which would not be reliably detected by an ATTC circuit or by differentiation since it does not have well-defined edges, and therefore it may be desirable to use a fixed threshold fault-detecting circuit in addition to an ATTC or differentiating circuit when testing.

A valid fault-indicating signal, i.e. a signal not generated in respect of a fault-invalid position of the beam as defined by the RAM, will not be suppressed and may be assumed to represent an actual fault in the container. However, it would generally not be desirable to reject a container on the basis of only a single or a very few valid fault-indicating signals since these may arise from noise in the electrical components of the systems, or from only small but acceptable faults or variations from the tolerance established by the contents of the RAM. Therefore, it is preferable in respect of each container to sum the number of valid fault-indicating signals and only reject when the total exceeds a predetermined limit. Where the signal processing circuit comprises several channels having different threshold levels, as mentioned above, rejection may take place either when the overall total of fault-indicating signals for all channels exceeds a certain limit, or when the total in respect of any one channel exceeds a certain limit which may be different for each channel.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawing whose single figure is a schematic diagram of an apparatus for inspecting bottles for faults.

Referring now to the drawing, the apparatus comprises a scanning zone 10, a conveyor 11 for transporting bottles 12 to and from the scanning zone 10 as indicated by the straight arrows, and a table 13 for rotating each bottle 12 about a vertical axis 14 substantially coincident with the axis of symmetry of the bottle while the latter is in the scanning zone 10. The apparatus further comprises means 15 for generating a spot-form beam of light 16 and causing such beam to repeatedly scan the bottle 12 at high frequency substantially along the vertical axis 14 while the bottle is rotating. After passing through the bottle 12, the beam 16 falls on a light collector 17 which provides a signal 18 representing the amount of light falling thereon from the beam after passing through the container 12.

The apparatus thus far described may be identical to that described in relation to figures 1 to 3 of U.K. Patent Specification 1 206 136 but using the light collector described in relation to figure 5 of U.K. Patent Specification 1 430 547, and for this reason is shown only in highly schematic form and is not described in detail herein. However, in order to take advantage of modern technology it is preferred to use a laser to provide the beam 16. Since such a beam is generated as a spot beam, the spot-defining masking slits of the apparatus described in U.K. Patent Specification 1 206 136 are not required, so that in order to maintain the laser beam on the

vertical axis 14 of the bottle it is necessary to prevent movement of the bottle 12 through an angle in the horizontal plane while the bottle is being rotated and scanned. Thus when a laser beam is used the prior arrangement is modified so that the table 13 carrying the bottle maintains the latter temporarily with its axis 14 in a fixed position while rotation and vertical scanning of the bottle takes place. This is a modification well within the capabilities of one skilled in the art.

Furthermore, also in order to take advantage of modern technology, the light collector 17 may be constructed as a matrix of photo-diodes disposed behind a diffusing screen and separated one from another by a grid of thin-walled boxes. Such a construction of light collector is described in our European Patent Specification No. 0016551. However, whereas in that previous Specification the outputs of the diodes were examined selectively to search for certain non-occulsive faults, in the present arrangement the diode outputs of the light collector are merely summed so as to provide the electrical signal 18 representing the total amount of light falling on the collector from the beam 16.

The signal 18 is amplified in a pre-amplifier 19 to provide a suitable level of signal for further processing. Next the amplified sum signal is passed to a fault-detection circuit 20, which can operate according to any desired criterion to detect faults, as hereinbefore discussed. However the preferred fault-detecting circuit 20 is that described in relation to figure 7 of our published European Patent Application No. 0037694. This circuit operates by differention and comparison with a reference threshold whose level is derived from the average transmission of the bottle at the point currently being scanned. Whatever form of fault detection is used, however, it involves a comparison of a signal derived from the light collector with a reference threshold level, and the circuit 20 is adapted to generate a pulse-form fault-indicating signal 21 for so long as the threshold is exceeded.

As the vertical scanning in the scanning zone is performed continuously as each container rotates through at least 360° it will be appreciated that the circuit 20 will generate fault-indicating signals not only in respect of actual faults, but also from certain regions of the container even when such container is acceptable. For example, a fault-detecting circuit operating by differentiation will provide a fault-indicating signal each time the beam meets the top of the container and leaves the bottom of the container, as well as at regions of heavy embossing or lettering depending upon the level of the reference threshold chosen for the fault-detecting circuit 20. It is therefore necessary to suppress those fault-indicating signals which are generated as a result of scanning a characteristic of an acceptable container. This is achieved by the use of a random access memory matrix (RAM) 22 comprising rows and columns of bit cells, and which contains binary information identifying those vertical positions of the beam (referred to herein as fault-invalid positions) in respect of which fault-indicating signals may be generated by an acceptable container according to the criterion used by the circuit 20 even though no actual fault is present in the container.

Before describing the testing of containers using the RAM 22, the method by which the binary information is stored in the RAM will first be described. This storage of binary information is performed during what may be called the "learning mode" of the system.

In the learning mode, the output of the circuit 20 is passed to a control circuit 23 for the RAM 22 via a switch 24, and the beam is set for continuous vertical scanning. Now a succession of containers which have been determined by other means to be acceptable are conveyed into the scanning zone 10 on the conveyor 11 and rotated on the Table 13. When each container is properly located on the table and rotating at the desired speed a "start" signal is provided on line 27 to control circuit 23, such signal persisting for a period of time corresponding to rotation of the container through at least 360°.

Upon receipt of the start signal, the control circuit 23 repeatedly addresses or scans down the same predetermined column of the RAM 22 in synchronism with and at the same repetition frequency as the vertical scanning of the beam, starting with the next vertical scan after the receipt of the start signal. To achieve synchronism of column addressing with the vertical scanning of the beam the control circuit has an input 29 which receives a signal at the beginning of each vertical scan from the scan generator 15. During the scanning of the memory, a binary 1 is set in the bit cell of the memory currently being addressed when a pulse-form signal 21 is present at the output of the circuit 20, the presence of a binary 1 in any given bit cell thereby indicating that a fault-indicating signal was generated in respect of the corresponding portion of the container. This is repeated for each vertical scan of the container, with a cumulative addition of binary 1 bits in the allocated column of the memory 22, until the control circuit 23 determines that the container has revolved through at least 360°, as indicated by the end of the signal on line 27.

The result, after a single container has passed through the scanning zone with the system in the learning mode, is a pattern of binary 1's in the allocated column of the memory 22 which corresponds to the pattern of fault-indicating signals generated by the acceptable container. This is repeated for a large number of acceptable containers (for example 50) with a further cumulative addition of binary 1 bits in the same column of the memory 22. By cumulative addition we mean that a binary 1 is inserted in a bit cell where one is not present from an earlier vertical scan of the same or a previous container, but previously inserted binary 1's remain. The final result therefore is a pattern of binary 0 bits in the allocated column of the memory 22 which defines those vertical scan positions of the beam 16 in

respect of which any fault-indicating signal can be regarded as resulting from an actual fault, and a complementary pattern of binary 1 bits identifying the fault-invalid positions of the beam.

When a sufficient number of acceptable containers have been passed through the system in the learning mode to provide a sufficient spread of binary 1 bits in the memory to accommodate all containers which could be regarded as acceptable, the learning phase is complete and the testing of containers can begin.

This is achieved by switching the output of the circuit 20 to a blanking circuit 25 via the switch 24, and passing the containers one by one to the scanning zone. In this "test mode" the scanning or addressing of the relevant column of the memory 22 is again triggered for each container by a start signal on line 27 and proceeds down the column in synchronism with and at the same repetition frequency as the vertical scanning of the beam, but this time the contents of the relevant column of the memory are non-destructively read out. Each time that a binary 1 is received by the control circuit 23 from the memory, the control circuit provides a blanking signal on line 28 to the blanking circuit 25. This ensures that any fault-indicating signal 21 which appears at the output of the circuit 20 is suppressed if it occurs while the beam is at a fault-invalid position. Thus those fault-indicating signals which do pass the blanking circuit 25 may be regarded as representing actual faults in the container.

As mentioned previously, it is preferable to enter the information into the RAM 22 in duplicate during the learning mode in order to mitigate against the effects of a faulty bit cell or the loss of information by incident cosmic or other particles. This may be readily achieved by entering the binary 1's generated during the learning mode into several different columns of the memory, each such column being addressed in identical manner in synchronism with and at the same repetition frequency as the scanning of the beam, so that (barring faults) the information in each column is identical in content and position. Then, during the test mode, a fault-indicating signal is suppressed if a binary 1 appears in any one or more of the columns of the memory in the bit cell corresponding to the current scan position of the beam.

As a further advantageous development, where the fault-detecting circuit 20 is the same as that described in relation to figure 7 of our published European Patent Application No. 0037694, it is desirable to provide a number of independently operating signal processing circuits or channels each similar to that portion of the accompanying drawing to the right of the pre-amplifier 19, and each receiving the output of the pre-amplifier 19 for processing in the manner described. This is shown schematically at 30 and 31. The processing in each channel is identical to that previously described, except that a different reference threshold level is set in the fault-detecting circuit 20 of each channel. The reason for this is as follows.

It will be seen from the description relating to figure 7 of our published European Patent Application No. 0037694 that the threshold level against which the differentiated signal is compared in the circuit 20 is a varying threshold which is a function of the average (smoothed) transmission of the container at the scanning point concerned, and varies in the same sense as the average transmission. The actual level of the threshold relative to the transmission of the container is determined by the setting of a potentiometer which taps off a proportion of the signal from the pre-amplifier 19 after smoothing. This enhances the sensitivity of fault-detection since it lowers the threshold level for denser portions of the container and vice versa. However, this is not wholly satisfactory where there are gross variations in the transmission through the container at different vertical positions thereof, since despite the variable threshold the sensitivity achieved is nevertheless still not constant over the full height of the containers, so that when the differentiated signal is compared with only a single (although variable) threshold level significant regions of the container are effectively excluded from inspection for faults.

For example, if the threshold level is set low by the potentiometer this will enable faults to be detected in the highly dense neck ring and push-up regions of the bottle. However, such a setting will in the learning mode provide fault-indicating signals in respect of most of the less dense parts of the bottle, so that in the subsequent test mode the memory 22 will not permit these parts to be effectively inspected since any fault-indicating signals arising from actual faults will be suppressed. On the other hand, a higher threshold level set by the potentiometer will enable effective fault detection in the clearer or less dense parts of the bottle, but will detect nothing in the dense areas.

The solution is therefore to provide a number of similar signal processing circuits each with the fault-detecting circuit set to a different threshold level as determined by its associated potentiometer, three such circuits or channels being provided in the present embodiment. The threshold levels are set by the respective potentiometers at low, medium and high respectively, the settings being chosen so as to maximise the area of bottle from which valid fault-indicating signals can be obtained by one or more of the channels.

The valid (non-suppressed) fault-indicating signals are counted in a counter 32 either together with any similar signals received from the processing circuits 30 and 31 or individually in respect of each such circuit to provide a container reject signal when for any container the total of valid fault-indicating signals in respect of any one fault-detecting circuit 20, or alternatively the overall total in respect of all three such circuits, exceeds a certain limit, as discussed earlier. In the latter case it is to be understood that the counter

32 is common to all three signal processing circuits, and has inputs (not shown) from the two circuits 30 and 31, and in the former case each circuit 30 and 31 has its own counter 32.

An alternative technique for suppressing the invalid fault-indicating signals (i.e. those signals which are generated in respect of a fault-invalid position of the beam is to store, in the test mode, the fault-indicating signals in a second RAM (which may be an unused part of the first RAM 22), the second RAM being addressed in synchronism with the vertical scanning in precisely the same way as the RAM 22 was addressed during the learning mode. Thus at the end of scanning a container the second RAM contains a pattern of binary 1 bits corresponding to the fault-indicating signals generated by that container. Now the control circuit 29 reads out and compares the contents of the two RAMs in the same sequence, and blanks any fault-indicating signal which occurs as output from the second RAM when the corresponding output from the RAM 22 is a binary 1.

In a practical example of this embodiment, the diameter of the spot beam of light is 1 mm at the container, and the beam makes several hundred vertical scans for a full revolution of the container, providing a considerable degree of overlap of consecutive scans. Furthermore, the memory is clocked at a rate corresponding to about 60 bit cells per vertical scan, so that one bit cell represents an element of length of about 1/60th of the vertical scan height of the beam. It is to be understood that the elements contained within the dotted rectangle in the drawing, and the functions performed thereby as described above, may be embodied in a suitably programmed commercially available microprocessor, using the control circuit and random access memory of the microprocessor.

As mentioned earlier, where the circuit of figure 7 of our published European Patent Application No. 0037694 is used both for initially generating the contents of the RAM 22 as well as for the subsequent container inspection, it is advantageous to set the reference threshold, as determined by the potentiometer, at a lower level during the learning mode of the system than during the subsequent test mode to accommodate undulations in the internal surface of the container.

The advantage of the present embodiment is that the system can be readily adapted to accommodate different shaped bottles or containers merely by providing a new set of binary information in the RAM 22 in the learning mode, thereby avoiding the time-consuming manual setting up operation referred to earlier. Furthermore, the stored information being in digital form is not subject to drift as were the analog values set in the prior art arrangement.

It is to be understood that although the embodiment described above uses a random access memory matrix for the storage of binary information defining the fault-invalid positions of the beam, it is envisaged that other kinds of storage means for binary information may be used.

CLAIMS

1. An apparatus for the inspection of translucent containers, the apparatus comprising a scanning zone, means for rotating a container within the scanning zone, means for generating a spot beam of light and causing it to repeatedly scan the container in a direction substantially parallel to the axis of rotation of the container, an opto-electronic light collector for providing a signal representing the amount of light falling thereon from the beam after transmission through the container, a fault detection circuit adapted to examine the signal from the light collector according to a predetermined criterion to generate a fault-indicating signal when such criterion is fulfilled, a digital storage means having stored therein binary information identifying those scan positions of the beam (referred to herein as fault-invalid positions) in respect of which fault-indicating signals may be generated according to the said criterion from an acceptable container, and suppression means responsive to the stored binary information for suppressing any fault-indicating signal generated in respect of a fault-invalid position of the beam, wherein the contents of the storage means are the cumulative result of previously scanning a large number of containers which have been determined to be acceptable, and storing a digital indication of each fault-indicating signal generated during each individual scan of the container at an address in the storage means corresponding to the current scan position of the beam.

2. An apparatus according to claim 1, wherein the suppression means comprises means for reading out the contents of the storage means in synchronism with each individual scan of the container, and means for blanking any fault-indicating signal which occurs simultaneously with an output of the storage means which identifies the current scan position of the beam as being a fault-invalid position.

3. An apparatus according to claim 1 or 2, wherein the fault detection circuit is adapted to differentiate the signal from the light collector so as to provide a further signal representing the rate of change of amplitude of the light collector signal, and to compare the further signal with a reference threshold level so as to generate a fault-indicating signal when the rate of change of amplitude exceeds the threshold level.

4. An apparatus according to claim 3, wherein the fault detection circuit is the same as that previously used in the operation of accumulating information in the storage means but has a higher reference threshold level.

5. An apparatus according to claim 3 or 4, wherein the reference threshold level at any point in the scanning is a function of the average transmission through the container at that point,

and varies in the same sense as the average transmission.

6. An apparatus according to claim 3, 4 or 5 wherein a plurality of similar fault detection circuits are provided each having a different reference threshold level, the apparatus further comprising means for individually summing the number of unsuppressed fault-indicating signals in respect of each such circuit and providing a container reject signal when the total in respect of any one such circuit exceeds a certain limit, or alternatively means for summing the overall number of unsuppressed fault-indicating signals in respect of all such circuits and providing a container reject signal when the overall total exceeds a certain limit.

7. An apparatus according to any preceding claim wherein the storage means comprises a random access memory.

8. An apparatus as claimed in claim 1, substantially as described with reference to the accompanying drawing.

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